QUANTITATIVE EMG

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Routine EMG studies gather qualitative data, based on viewing waveforms on the EMG machine's screen, and abnormalities are expressed in terms of 1+ to 4+ increases or decreases in a number of metrics (abnormal spontaneous activity; motor unit recruitment, motor unit amplitude, motor unit waveform duration and complexity). Qualitative EMG assessments are rapid, and generally detect large abnormalities, and the ranking is sufficient to be appreciated when reading a report.

Quantitative EMG (QEMG) is based on discrete numbers to describe the above metrics, and are expressed in millivolts, milliseconds, etc. QEMG assessments may take more time, but are more sensitive to subtle abnormalities, and amenable to statistical analysis. QEMG is based on enhanced EMG computer software available on modern machines. A number of QEMG techniques are available and this session will review quantitative motor unit analysis, analysis of turns and amplitude, motor unit number estimation (MUNE), and motor unit index (MUNIX).

There is also a technique that combines a quantitative approach to routine EMG studies, coined as semi-QEMG. This approach can be set up on any EMG machine, and adds a degree of precision to routine studies. Semi-QEMG will also be presented.

Routine qualitative EMG is based on a "feeling" for the size and shape of motor units, but the feeling in turn is based on data gathered in the 1950's that quantified motor unit metrics. At that time, motor units were photographed and measured manually, and average data on amplitude, duration, and complexity compiled as "normative data." Motor unit assessments during routine EMG are based on these early QEMG efforts. With the advent of computer processing in modern EMG machines, similar motor unit data can be gathered and compiled within seconds, and a muscle characterized quantitatively within a minute. Software programs are proprietary for specific EMG machines, and have different names, but are based on similar operations performed on EMG signals. At a site within a muscle, with mild voluntary contraction, the needle electrode is close to 4 or more motor units. The software records 10-30 sec of signal, converts it to digital format, and then detects each waveform. Identical waveforms are recognized and stored, averaged, and the onset and termination marked for each detected motor unit based on a uniform marking algorithm. By moving the electrode to different sites, a total of 20 or more motor units are collected for a muscle, and summary statistics calculated. The resultant table provides information on mean amplitude, duration, turns and phases, and discharge rate for the muscle, and there are derived metrics not available from visual inspection, such as motor unit area and area/amplitude ratio. A patient's data can be compared to normative data. It is advisable to collect normal data using the investigator's EMG machine and particular needle study technique. QEMG is most useful to adjudicate between neuropathic and myopathic conditions, and normative data can be gathered on a few informative muscles, such as biceps brachii, deltoid, and the vasti.

The semi-QEMG technique is based on using a trigger and delay line to extract and view on a second screen individual motor units from the mild interference pattern to better visualize abnormalities of amplitude, duration, and turns and phases. This allows for recruitment to be expressed as maximum discharge frequency (eg, 20Hz versus 2+ reduced), amplitude to be expressed in round numbers (eg, 4KmV versus 2+ increased), duration estimated numerically (eg, a few > 12ms versus 2+ increased), complexity as the average number of phase and turns, and whether motor unit waveforms are stable or unstable. This process can be readily incorporated into the routine EMG studies and requires no greater time.

The complexity of the EMG interference pattern varies with contraction effort, from a few motor units to a "full" pattern. The fullness of the pattern is usually visually estimated, but can be quantitated. As the pattern increases, more motor units are added, resulting in higher amplitude and more complex signals. Software available on EMG machines can determine from an interference pattern the number of turns per second (changes in the signal from positive to negative) and the average amplitude of the turns. For every level of contraction there is a unique value of turns and amplitude, which can be plotted, and is called "Analysis of Turns and Amplitude." With a neuropathic disorder, there are fewer motor units and many motor units are higher in amplitude; with a myopathic disorder, there are more complex motor units with more turns and many motor units are lower in amplitude. Turns and Amplitude plots document this change.

It would be desirable to be able to determine the number of motor neurons innervating a muscle, especially in neuropathic disorders. This is not possible with routine electrodiagnostic tests: while the amplitude of the compound muscle action potential (CMAP) is proportional to the number of axons, collateral reinnervation buoys up the amplitude with mild loss, and it is not until loss is ~50% that the CMAP falls below the laboratory's lower limit of normal. While reduced recruitment on needle EMG indicates fewer motor neurons, estimates are qualitative. The issue is that motor units cannot be counted, either anatomically or electrically, but can be estimated by the technique of motor unit number estimation (MUNE). MUNE is based on the ratio of the maximal CMAP divided by average single motor unit size. The CMAP is obtained by routine techniques while isolation of single motor units can be accomplished by different methods. MUNE has been used most often in investigations of amyotrophic lateral sclerosis (ALS) and spinal muscular atrophy (SMA). There are limitations to the technique, and it is time consuming. However, information from research studies provides useful clinical information, which will be reviewed.

A related technique to MUNE has been developed that analyses the interference pattern at several levels of contraction and calculates an index that is felt to reflect the number of motor units innervating the muscle. It is called Motor Unit Number Index (MUNIX), and an advantage is that it can be performed rapidly, but requires proprietary software.